CORNING GLASS WORKS

ELECTRO-OPTICS LABORATORY

RALEIGH, NORTH CAROLINA

IMPROVED SCREEN FOR REAR PROJECTION VIEWERS

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I. Beaded Screens

A. Types of Screens

In order to discuss the optical characteristics of beaded screens and to understand the trade-offs involved, it is convenient to distinguish between two basic types of beaded screens, type I and type II. Type I screens are designed so that the beads face the viewer, as shown in Fig. 1, while type II screens are designed so that the beads face the projector, as shown in Fig. 2. It will be shown that the optical properties of these two screen types are significantly different, but result from the same phenomena. The parameters governing the optical behavior of a beaded screen are the refractive indices n_1, n_2, and n_3, which are defined for each screen type in Figures 1 and 2. For type I screens $n_3/n_1 \leq 1$, while for type II screens $n_3/n_1 > 1$, so that in the following discussion if screen type is not explicitly stated, it may be inferred from the value of n_3/n_1.

B. Results of Theoretical Investigation

The theoretical work concerning the optical properties of glass beads has been completed, and only the results are summarized here. A full discussion with all data will be contained in a later report.

Axial gain as a function of n_1/n_2 for various values of n_3/n_1 is plotted in Figures 3 and 4 for type I and type II screens, respectively. A wide range of axial gain values is available with either type screen; however for a given n_1/n_2 value, type I screens generally have smaller axial gain values than do type II screens.

In Fig. 5, the fraction of the incident energy contained within a $\pm$ 45^{o} solid angle, T_{45}, is plotted as a function of axial gain for various values of n_3/n_1. Note that as n_3/n_1 increases from 0.6 to 1.0, T_{45} increases considerably for a given axial gain, while further increase of n_3/n_1 to 1.4 results in little additional change in the curve. For a given axial gain, the efficiency of a type II screen is comparable to that of a non-absorbing diffusing screen, but type I screens generally have a lower efficiency than corresponding diffusing screens. In type I screens a significant fraction of the projector light suffers total internal reflection within the beads and is lost to the viewer, which accounts for the lower efficiency.

Figure 6 shows curves of brightness variation over $\pm$ 45^{o} as a function of axial gain, for various values of n_3/n_1. The trend is that for a given axial gain, brightness variation decreases as n_3/n_1 increases up to 1.0, and little change occurs as n_3/n_1 is increased to 1.4. For n_3/n_1, > 1, the brightness variation is comparable to that of a corresponding diffusing screen, while for $n_3/n_1 < 1$ the brightness variation is generally greater than that of a corresponding diffusing screen.

Ambient light sensitivity of both types of beaded screens is low, but type I screens are superior to type II screens in this respect. Total internal reflection in type I screens causes a considerable portion of the projector light to be reflected back toward the projector, and efficiency is decreased; however the screen is highly transparent to light incident on the viewing side, and low ambient light sensitivity results. Type II screens are highly transparent to projector light, i.e. highly efficient, but now a significant fraction of the ambient light striking the screen is totally reflected within the beads, and the ambient light sensitivity is increased. The diffuse reflectance of some typical type I beaded screens has been measured to be 6%, which is equal to that of the best commercial screens (which contain absorbing material), while the diffuse reflectance of some typical type II screens has been measured to be 18%. Another undesirable feature of the type II screen is that ambient light is specularly reflected from the plane glass surface.

C. Advantages and Disadvantages

Beaded rear projection screens have some significant advantages over presently available screens. Screens having a wide variety of viewing characteristics can be fabricated by simply varying the refractive indices of the glass beads and the embedding resin. <u>Ambient light sensitivity is low, even for low-gain screens</u>, whereas low-gain diffusing screens are very sensitive to ambient light. For a given axial gain, brightness variation of type II screens is comparable to that of non-absorbing diffusing screens. Color fidelity is very good, because the beaded screen operates by refraction rather than scattering.

A problem with the present beaded screens is that projector light is transmitted through the lenticular void areas between adjacent beads, and this causes measured values of axial gain to be greater than theory predicts. This problem can be eliminated by a suitable masking technique, and work is continuing in this area. Another trade-off is that for low gain type I screens, losses caused by total internal reflection can be excessive, and low values of T_{45} result. While type II screens are as efficient as non-absorbing diffusing screens, specular reflections from the viewing side of the screen can be objectionable.

In view of the above discussion, beaded screens seem to be competitive with present commercial screens, and masking should give a further improvement.

II. Ceramic Powder Screens

Work is continuing in the area of ceramic powder screen fabrication, and some fair quality screens have been obtained. Several of the most promising glass ceramic materials have been selected, and five pound quantities of each material will be ground into powder for use in screen fabrication.

Figure 1. Beaded Screen Having Beads Toward The Viewer

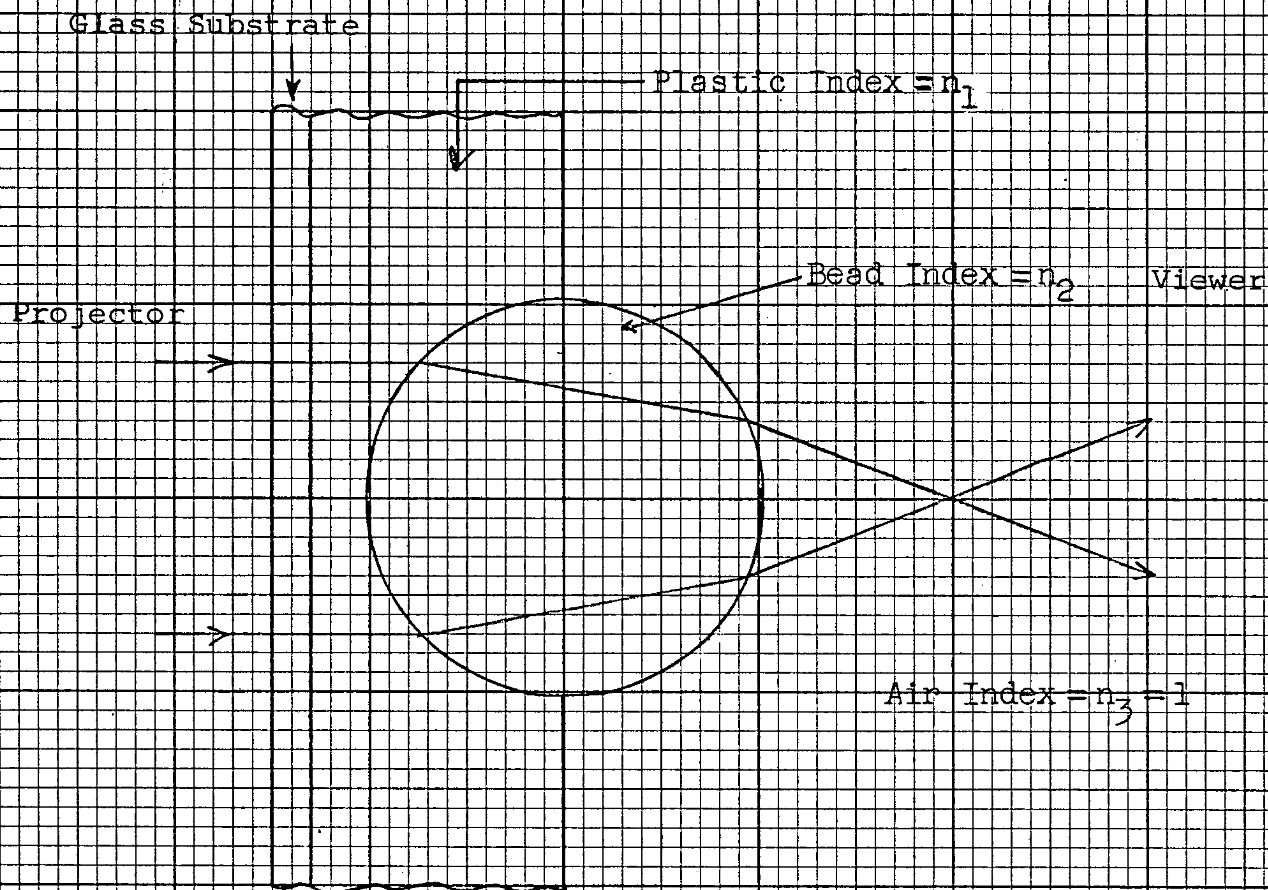
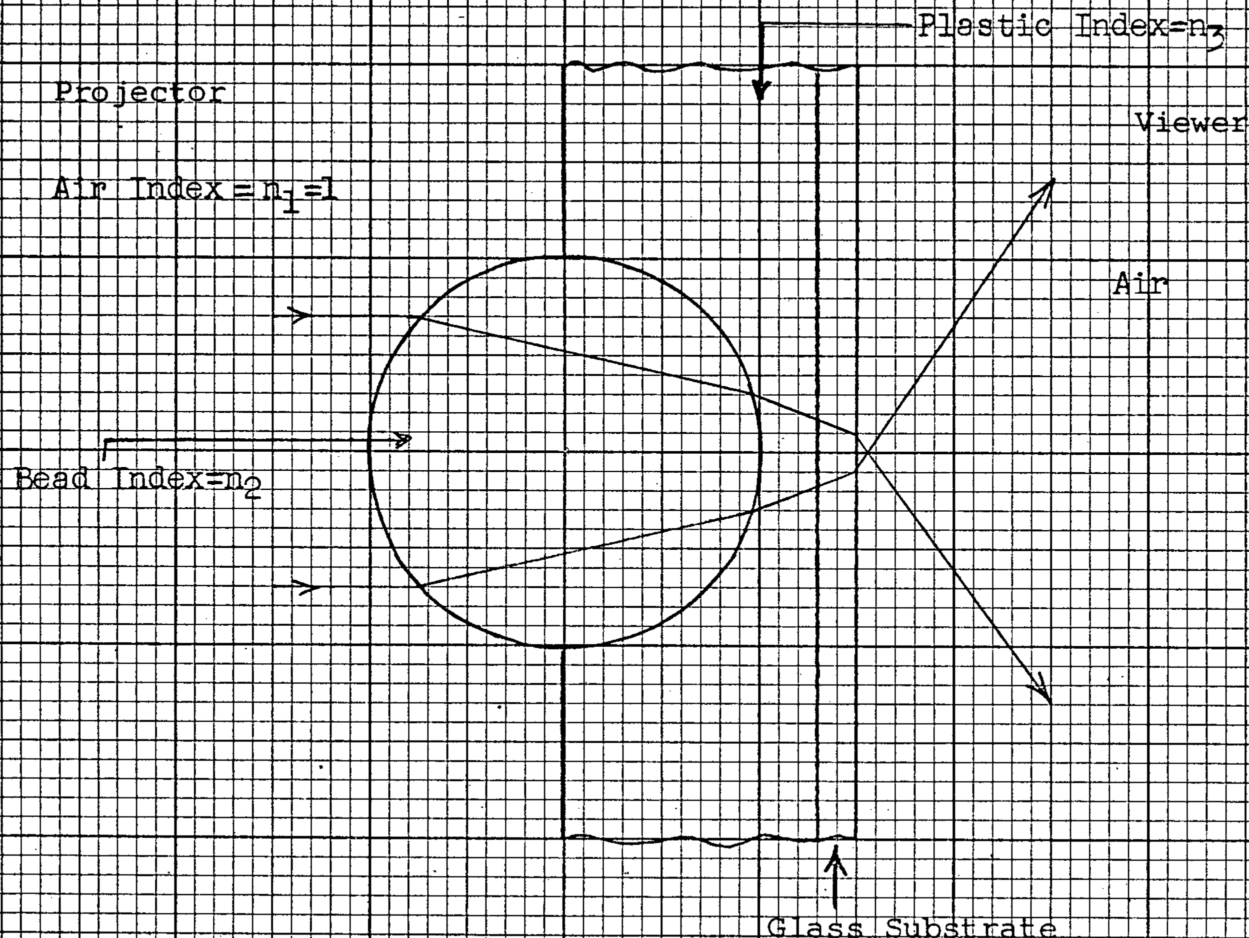


Figure 2. Beaded Screen Having Beads

Toward the Projector - Type II



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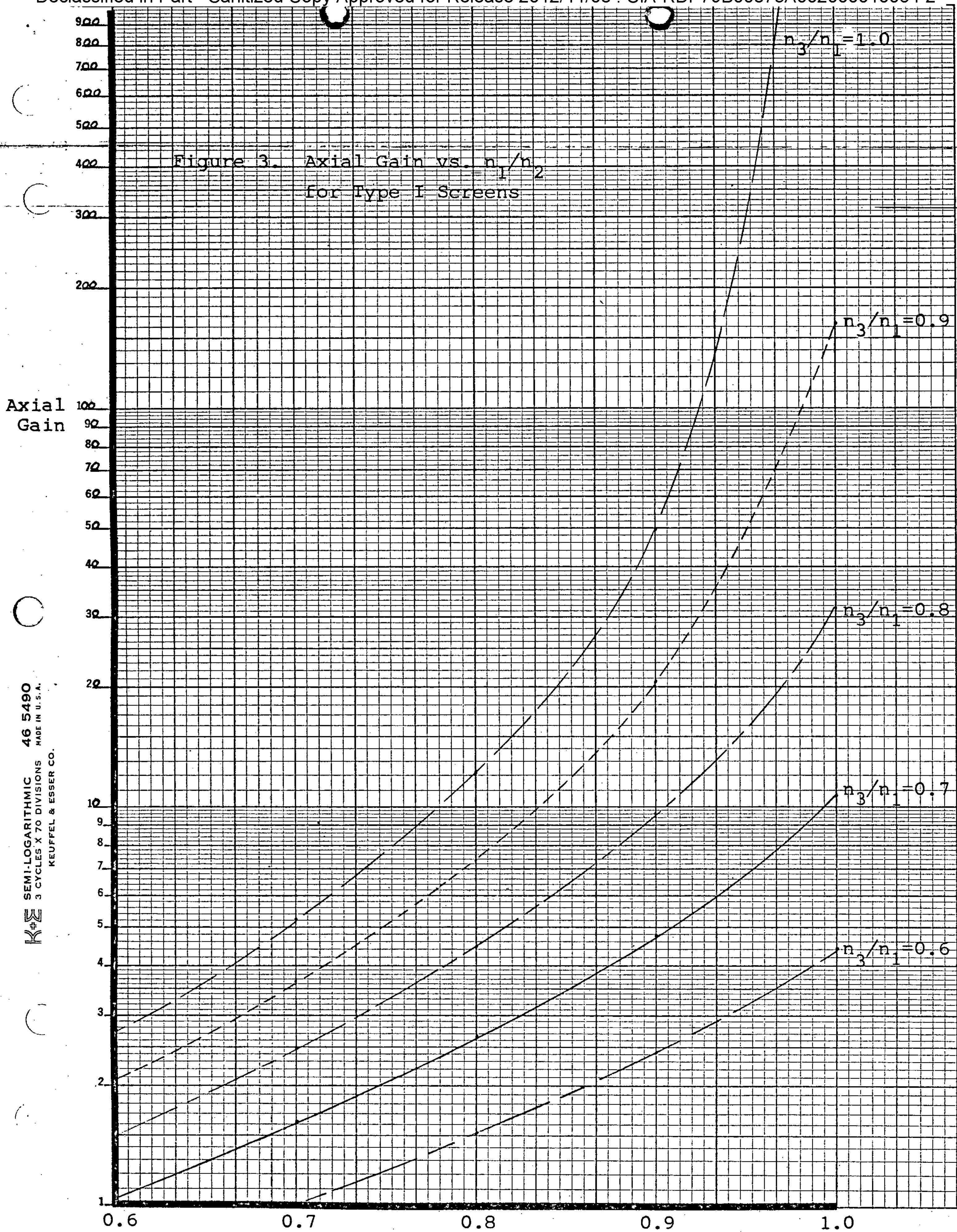
Figure 3. Axial Gain vs. n_1/n_2 for Type I Screens
Axial Gain
$n_3/n_1=1.0$
$n_3/n_1=0.9$
$n_3/n_1=0.8$
$n_3/n_1=0.7$
$n_3/n_1=0.6$
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0.6
0.7
0.8
0.9
1.0
SEMI-LOGARITHMIC 46 5490
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

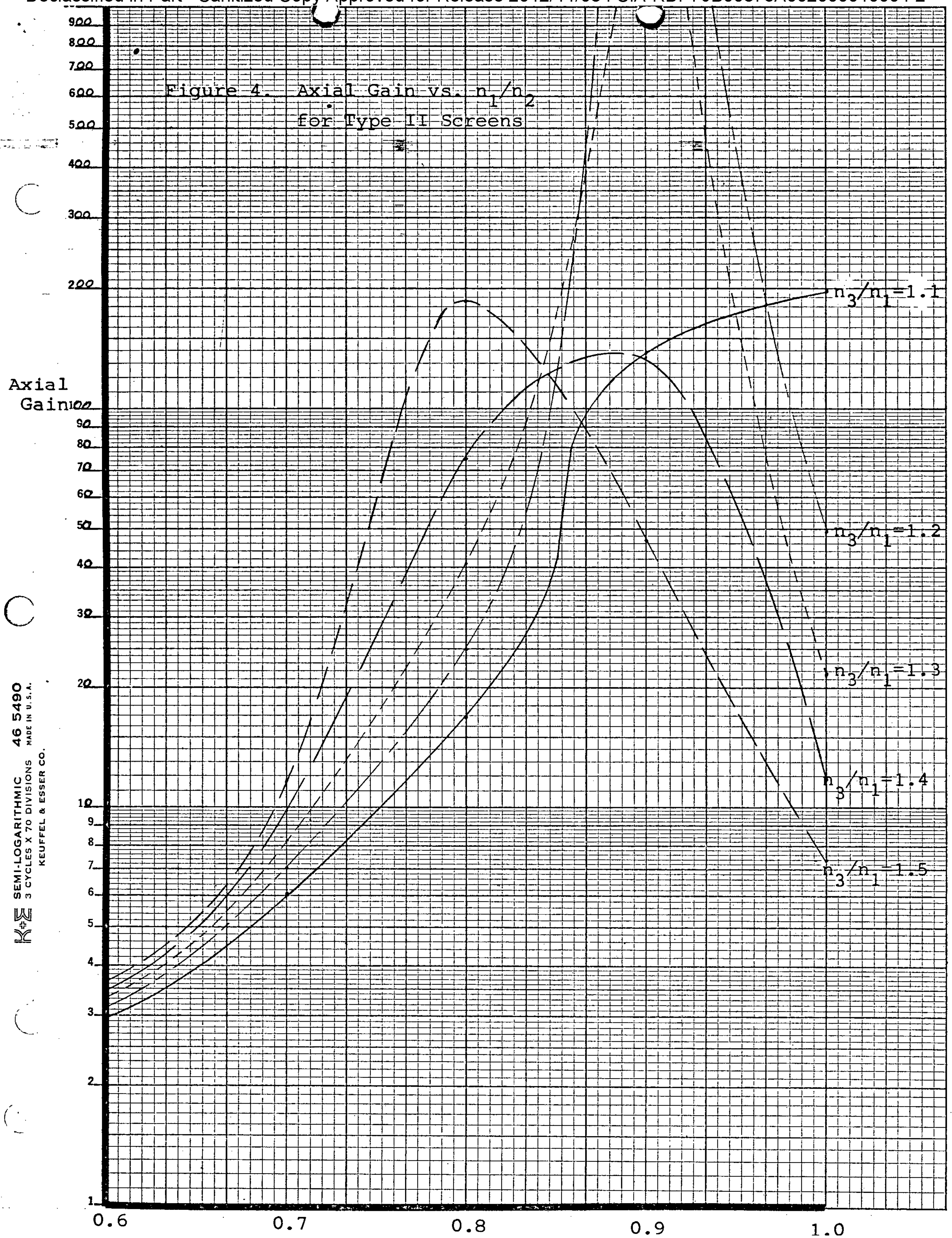
Figure 4. Axial Gain vs. n_1/n_2
for Type II Screens
Axial Gain
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0.6
0.7
0.8
0.9
1.0
$n_3/n_1=1.1$
$n_3/n_1=1.2$
$n_3/n_1=1.3$
$n_3/n_1=1.4$
$n_3/n_1=1.5$
SEMI-LOGARITHMIC 46 5490
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

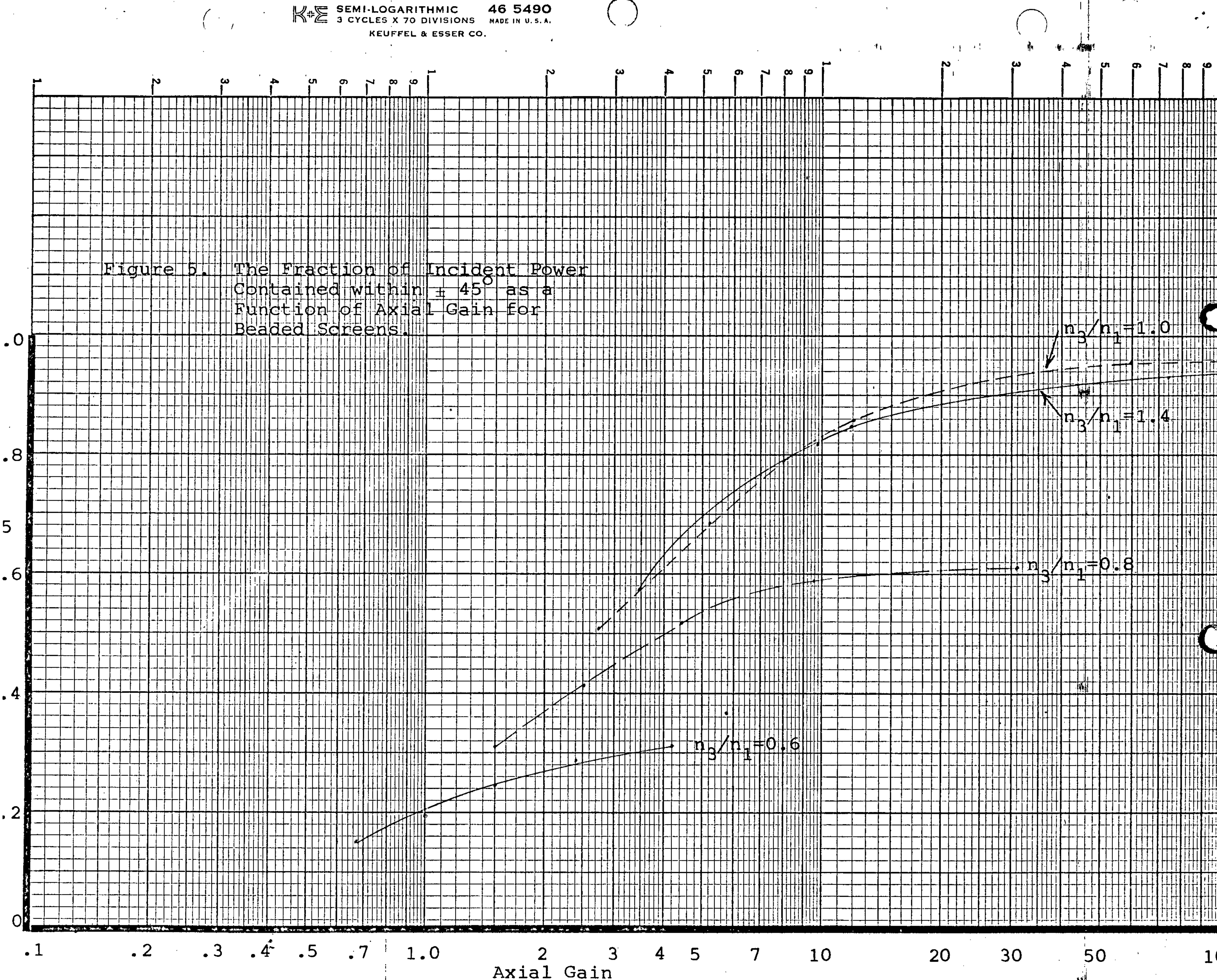

Figure 5. The Fraction of Incident Power Contained within ± 45° as a Function of Axial Gain for Beaded Screens.

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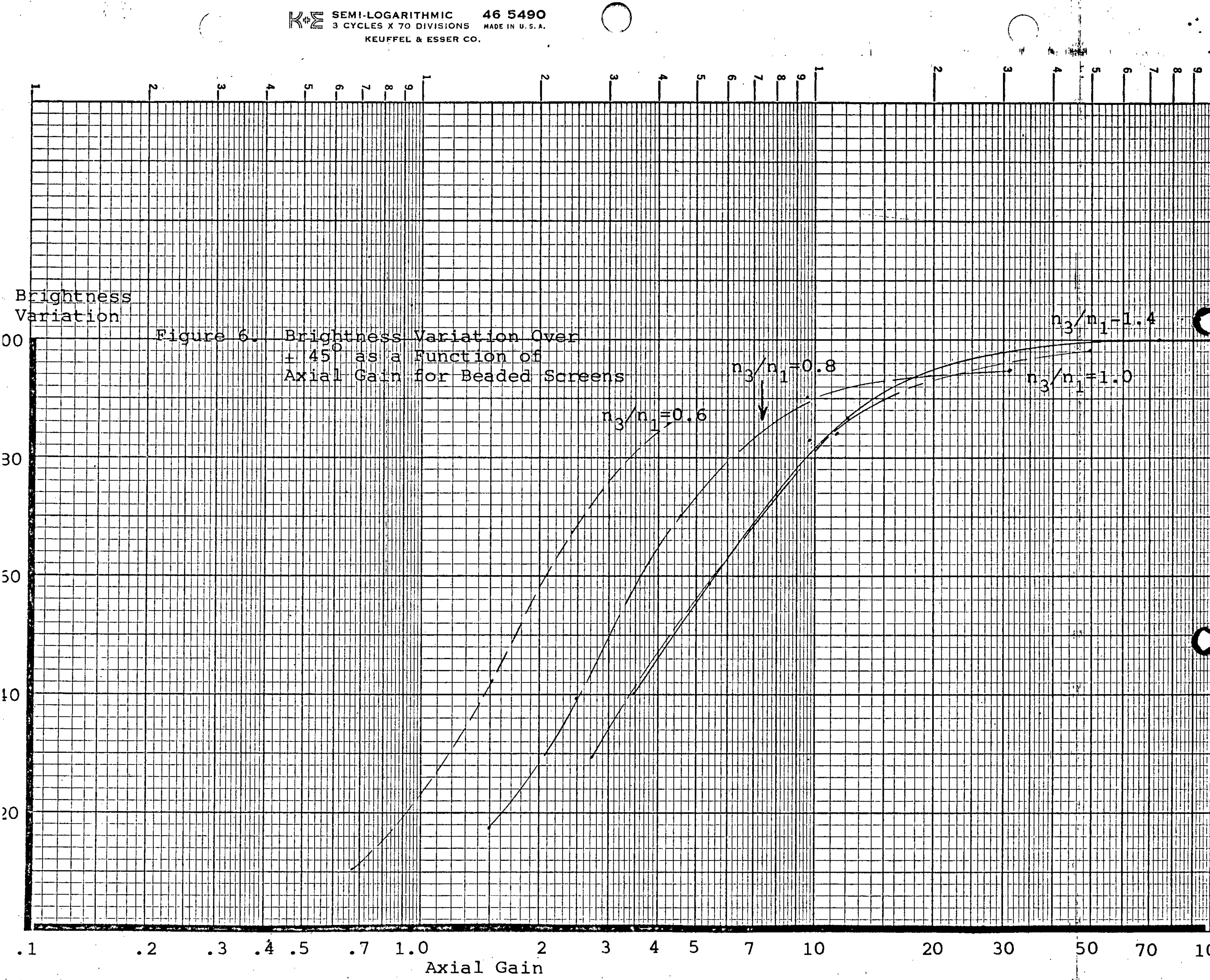

Figure 6. Brightness Variation Over ± 45° as a Function of Axial Gain for Beaded Screens